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FINAL REPORT FOR THE C-130 RAMP TEST #3 OF A HYDREMA MINE CLEARING VEHICLE

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1.0 INTRODUCTION

1.1 General

The Air Force Research Laboratory (AFRL) located at Tyndall Air Force Base (AFB) in Panama City FL, has coordinated with the Physical Simulation Team (PST) at the Tank Automotive Research, Development, and Engineering Center (TARDEC) located in Warren MI, to perform a third C-130 ramp test on the Hydrema Mine Clearing Vehicle (MCV). This test is being conducted to determine if the new rear bogie system on the Hydrema will allow the vehicle to meet the requirements to be considered C-130 transportable.

The Air Force has strict specifications for loading any vehicle onto a C-130. Those specs state that the axle weights of the vehicle can not exceed 13,000 lbs. This weight limit applies to the ramp of the plane as well as the floor of the aircraft.

1.2 Testing of the System

The test was conducted on February 5-7, 2008. The test consisted of several preliminary runs that were used to adjust the newly developed rear bogie system for optimal performance. Three final test runs were then conducted with the ramp at a 12 degree angle, and those results will be presented in this report. In addition 2 other test cases were investigated and recorded in order to allow the vehicle stay below the maximum height of 110" inside the aircraft.

The Hydrema vehicle was driven slowly up the ramp shown in Figure 1. The ramp has 16 instrumented plates that are shown as letters A-P. Each plate has four load cells, one in each corner, and is capable of measuring up to a 20,000 lb load. The vehicle made several stops as it climbed the ramp in order to take clear readings of the tire forces at various locations.

In order for the Hydrema to be considered C-130 transportable by the US Air Force, it must not exceed an axle load of 13,000 lbs anywhere on the ramp. To achieve this goal, the Hydrema vehicle has a set of bogie wheels in the front and a double set of bogie wheels in the rear that are installed just to load the vehicle onto the aircraft.

2.0 TEST SETUP

2.1 Test Equipment

In order to monitor the weight of a vehicle as it is loaded into a C-130, two axial load measurement ramps have been designed, fabricated, and instrumented with load cells (See Figure 1). The load cells are wired to a data acquisition system and data is sampled continuously while the vehicle is loaded on and off the ramp. The ramp has 16 instrumented plates (A-P in Figure 1), that are 32" square. Each plate has four 5,000 lb load cells, one in each corner. This allows each plate to record loads up to 20,000 lbs. The load cells are wired to a summing box, also located on the bottom of the plate, where the readings from all 4 load cells are added together and sent to the data acquisition system. The plates can be reconfigured to take measurements as the vehicle climbs the ramp, on the floor of the plane, or a combination of both. The ramp angle can be changed from 12 to 15 degrees. For this test, the ramp will be left in the 12 degree configuration. It should be noted that plates P and H are in reverse order for this test.

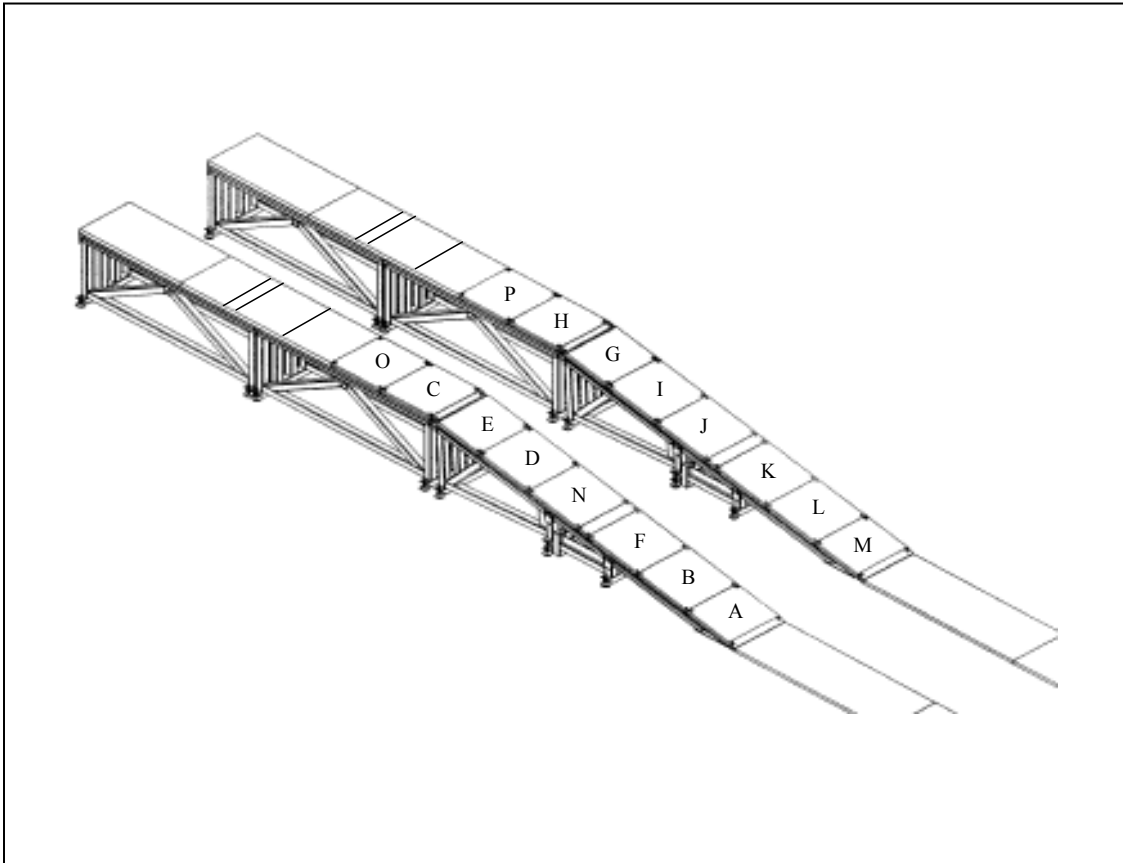


Figure 1. C-130 Measurement Ramps

2.2 Vehicle Configuration

The Hydrema MCV is a four wheeled vehicle that weighs over 36,000 lbs. The vehicle has been equipped with a special hydraulic bogie wheel system that is specifically for loading into the C-130. This bogie system is shown in figures 2 and 3. Hydraulic cylinders force the bogie wheels down to the ground and essentially lift the vehicle up, taking some of the weight off the main axles and transferring it to the bogie axles. The hydraulic cylinders are run off of the vehicles main hydraulic system so no additional pumps or fluid need to be mounted to the vehicle. It is believed that these bogie axles will allow the Hydrema to meet the 13,000 lb axle limit. It should be noted that the rear bogie wheels will be treated as one axle, at the request of the Air Force, due to the small spacing between the two wheels. The center of the bogie axle will be the midpoint between the two tires.



Figure 2. Hydrema Front Bogie Axle



Figure 3. Hydrema Rear Bogie Axles

The Hydrema also has its flail system rotated and stowed on the rear of the vehicle (Figure 4). All the chains and hammers for the system have been removed for transport.



Figure 4. Stowage of flail system

The axle spacing and overall length of the vehicle in its C-130 transport configuration are shown in Figure 5.

2.3 Test Procedure

The test plan is to drive the Hydrema up the ramp and determine where the highest axle load readings will be found. After determining the worst case position, adjustments will be made to the bogie system to optimize the system. Upon achieving acceptable results, 3 final runs will be completed to show that the data is correct and repeatable. Due to small changes in position and alignment of the vehicle, the weight changes slightly from run to run. The final axle weight will be obtained by taking the average of the three runs.

3.0 Results

It was determined that the peak axle loads were measured as the front main vehicle axle, and the rear bogie axle crossed over the hinge pin. This is where the top of the ramp is connected to the fuselage of the aircraft. For the three final test runs, the vehicle was paused just before first contact with the hinge pin, when the tire is centered on the hinge pin, and just after it clears the hinge. The rear bogie axle was measured in 6 positions, just before, on, and just over the hinge pin for both tires.



Figure 5. Vehicle dimensions

Several optimization test runs were completed. During these test runs the hydraulic pressure used in both the front and rear bogie axles were adjusted along with changing the tire pressures for the main axles. The tire and hydraulic pressures used for the final test runs are shown in Table 1 below.

Table 1. Tire and Hydraulic Pressures

	Test Case #1	Test Case #2	Test Case #3
Tire Pressures			
Front Axle	20 psi	19 psi	40 psi
Rear Axle	40 psi	40 psi	40 psi
Bogie Axles	100 psi	100 psi	100 psi
Hydraulic Pressures			
Front Bogie System	159 bar (2306 psi)	140 bar (2031 psi)	140 bar (2031 psi)
Rear Bogie System	154 bar (2234 psi)	154 bar (2234 psi)	154 bar (2234 psi)
Fuel level in vehicle	Tank was $\sim 1/4$ full.	Tank was $\sim 1/4$ full.	Tank was $\sim 1/4$ full.

The results for the final 3 test runs for each test scenarios can be found in the Appendix section of this report. Appendix A shows the results for scenario 1, Appendix B shows the results from scenario 2, and Appendix C shows the results for scenario 3. The average weight for the 3 runs can be found in Appendix D. This data shows that at no time during the loading of the Hydrema does any single axle exceed the 13,000 lb load limit.

4.0 Conclusion

The data from this testing supports that the Hydrema MCV passes the axle restrictions placed on vehicles that are considered for C-130 transport. As long as the tire pressures and hydraulic pressures in the bogie axles are maintained, the loading is repeatable as demonstrated in these tests.

Appendix A
Test Scenario 1
Ramp data recorded at 12 degree angle. All weights are in pounds.

Test Run 8	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	6705	11018	9997	12090	12111
On Hinge	6573	11231	9598	11955	12084
After Hinge	6552	11136	8980	12101	12169
Test Run 9	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	6642	10879	10146	12070	12030
On Hinge	6569	11125	9911	12008	11945
After Hinge	6506	10918	9179	11930	11927
Test Run 11	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	6659	10844	10063	12092	12159
On Hinge	6592	10963	9624	12064	12121
After Hinge	6573	11038	9026	12150	12146

Appendix B
Test Scenario 2
Ramp data recorded at 12 degree angle. All weights are in pounds.

Test Run 14	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	5949	11995	9485	12079	12161
On Hinge	5821	12137	9140	11994	12183
After Hinge	5865	12075	8470	12116	12136
Test Run 15	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	6006	11907	9487	12082	12129
On Hinge	5818	12105	9101	12026	12156
After Hinge	5957	11922	8560	12116	12060
Test Run 16	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	5936	11922	9670	12001	12016
On Hinge	5840	12122	9093	11872	12044
After Hinge	5870	12056	8584	12017	12004

Appendix C Test Scenario 3

Ramp data recorded at 12 degree angle. All weights are in pounds.

Test Run 17	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Before Hinge	5938	11970	9527	12166	12298
On Hinge	5912	12055	8851	12092	12225
After Hinge	5943	12043	8354	12208	12289
Test Run 18					
Before Hinge	5963	11959	9509	12140	12206
On Hinge	5884	12085	8950	12080	12174
After Hinge	5920	12054	8394	12214	11975
Test Run 19					
Before Hinge	5912	12043	9505	12161	12179
On Hinge	5827	12102	9177	12041	12081
After Hinge	5864	12072	8306	12147	11971

Appendix D Average axle weights for the 3 final test runs for each scenario. All weights are in pounds.

Average Weights	Front Bogie Axle	Front Axle	Rear Axle	Rear Bogie Tire 1	Rear Bogie Tire 2
Scenario #1					
Before Hinge	6669	10914	10069	12084	12100
On Hinge	6578	11106	9711	12009	12050
After Hinge	6544	11031	9062	12060	12081
Scenario #2					
Before Hinge	5964	11941	9547	12057	12102
On Hinge	5826	12121	9111	11964	12128
After Hinge	5897	12018	8538	12101	12067
Scenario #3					
Before Hinge	5938	11991	9514	12156	12228
On Hinge	5874	12081	8993	12071	12160
After Hinge	5909	12056	8351	12190	12078

Addendum to Hydrema Ramp Test Final Report Dated Feb 13, 2008
Additional Vehicle Weight Information

This addendum shows additional Hydrema weight information that was recorded February 27, 2008 with the vehicle on the ground instead of on the C-130 ramp. Three cases were recorded; just the vehicle on its main axles, the vehicle on its main axles with bogie wheels engaged, and the vehicle on its main axles with shoring in place. The tables below show the results of these tests and the figures show how the load plates were configured and how the shoring was set up.

Table A1. Weight of the vehicle sitting on just its main axles.

	Test 3	Test 4	Test 5	Average Wheel Wt.
Front Left	9025	9054	9067	9049
Front Right	9930	9947	9909	9929
Rear Left	9196	9251	9252	9233
Rear Right	9609	9580	9581	9590
				Ave Vehicle Wt
Vehicle Wt.	37760	37832	37809	37800

Table A2. Weight of the vehicle with the bogie axles engaged.

	Test 3	Test 4	Test 5	Average Axle Wt.
Front Bogie Axle	6173	6126	6108	6136
Front Axle	12899	12838	12871	12869
Rear Axle	6183	6497	6522	6401
Rear Bogie Axle	12570	12272	12238	12360
				Ave Vehicle Wt
Vehicle Wt	37825	37733	37739	37766



Figure A1. Load plate configuration used to measure the weight of the vehicle on just the main axles only, and with the bogie axles engaged.

Table A3. Weight on all ground contact points with the shoring installed.

	Test 1	Test 2	Test 3	Ave wt
Shoring under cab front left	2614	2654	2626	2631
Shoring under cab front right	1972	2029	2035	2012
Front Left Tire	5475	5462	5483	5473
Front Right Tire	6242	6257	6275	6258
Shoring under cab rear left	767	647	680	698
Shoring under cab rear right	376	307	302	328
Shoring under flail front left	2729	2775	2751	2752
Shoring under flail front right	940	946	919	935
Rear Left Tire	5977	5975	5962	5971
Rear Right Tire	6331	6322	6307	6320
Shoring under flail rear left	757	843	831	810
Shoring under flail rear right	4000	3968	4029	3999
Hydrema total wt with shoring	38180	38185	38200	38188

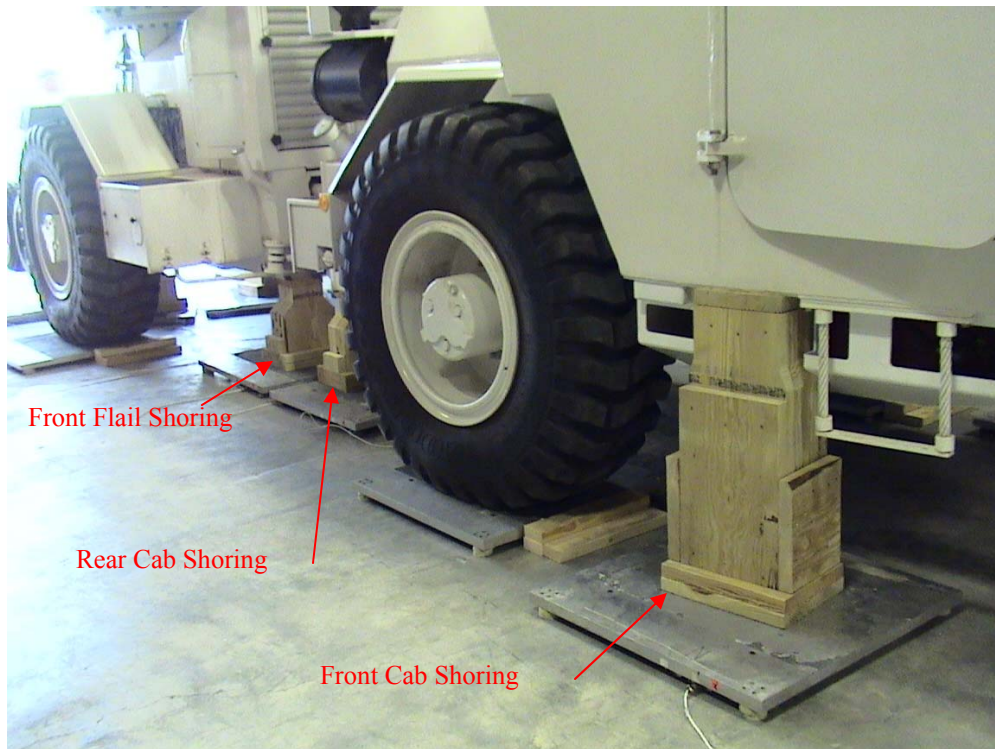


Figure A2. Shoring under cab and front of flail.



Figure A3. Shoring under rear of flail.

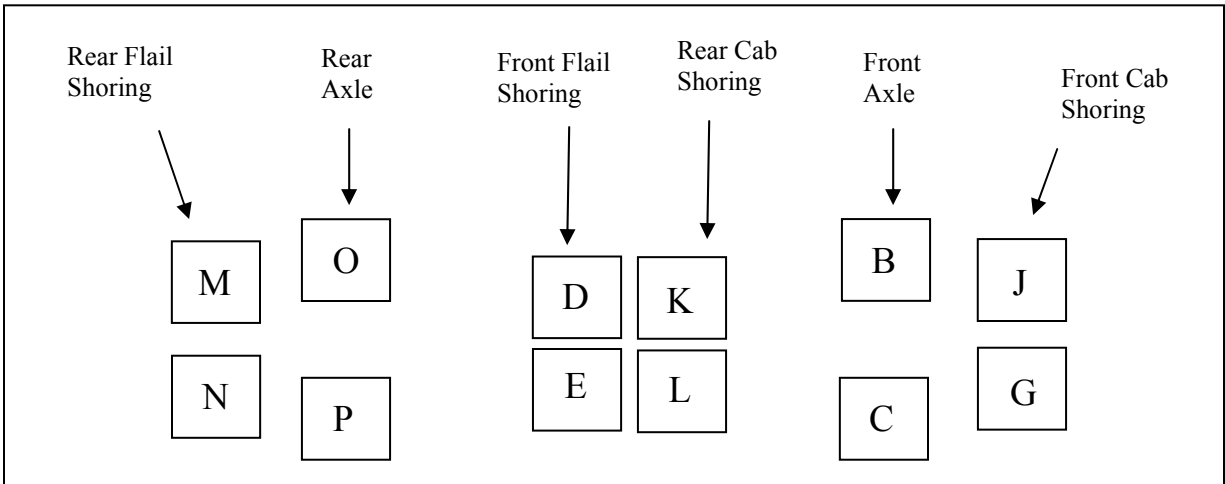


Figure A4. Load Plate configuration for weight measurements with shoring.

Table A4. Tire and Hydraulic Pressures

	Main Axle Tests	Main Axles w/ Bogies Test	Main Axles w/ Shoring Tests
Tire Pressures			
Front Axle	40 psi	40 psi	30 psi
Rear Axle	40 psi	40 psi	40 psi
Bogie Axles	100 psi	100 psi	100 psi
Hydraulic Pressures			
Front Bogie System	145 bar (2103psi)	145 bar (2103psi)	145 bar (2103psi)
Rear Bogie System	154 bar (2234 psi)	154 bar (2234 psi)	154 bar (2234 psi)
Fuel level in vehicle	Tank was <¼ full.	Tank was <¼ full.	Tank was <¼ full.